

Quantization of Planck Constants and Dark Matter Hierarchy in Biology and Astrophysics

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Abstract

The work with von Neumann algebras known as hyper-finite factors of type II_1 associated naturally with quantum TGD, led to a proposal for the quantization of the Planck constants associated with the symmetry algebras in M^4 and CP_2 degrees of freedom as $\hbar(M^4) = n_a \hbar_0$ and $\hbar(CP_2) = n_b \hbar_0$. A generalization of the notion of imbedding space emerged as a geometric realization of the quantization in terms of Jones inclusions. As a consequence, also a quantization of the Planck constant appearing in Schrödinger equation emerges and is given by $\hbar/\hbar_0 = \hbar(M^4)/\hbar(CP_2)$. "Ruler and compass" integers correspond to a very restricted set of number theoretically preferred values of n_a and n_b . In this article the quantization of Planck constant and some of its astrophysical and biological implications are briefly discussed.

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1 Introduction

D. Da Rocha and Laurent Nottale, the developer of Scale Relativity, have ended up with an highly interesting quantum theory like model for the evolution of astrophysical systems [2]. In particular, this model applies to

planetary orbits. Nottale predicted Bohr model like quantization for radii of planetary orbits in his book *Fractal Spacetime and Microphysics* published 1993. The quantization was later discovered for exoplanets [1].

1.1 The model of Nottale and DaRocha

The model is simply Schrödinger equation with Planck constant \hbar replaced with what might be called gravitational Planck constant

$$\hbar \rightarrow \hbar_{gr} = \frac{GmM}{v_0} .$$

Here I have used units $\hbar = c = 1$. v_0 is a velocity parameter having the value $v_0 = 144.7 \pm .7$ km/s giving $v_0/c = 4.6 \times 10^{-4}$. The peak orbital velocity of stars in galactic halos is 142 ± 2 km/s whereas the average velocity is 156 ± 2 km/s. Also sub-harmonics and harmonics of v_0 seem to appear.

The model makes fascinating predictions which seem to hold true. For instance, the radii of planetary orbits fit nicely with the prediction of the hydrogen atom like model. The inner solar system (Mercury, Venus, Earth, Mars) corresponds to v_0 and outer solar system to $v_0/5$.

The predictions for the distribution of major axis and eccentricities have been tested successfully also for exoplanets. Also the periods of 3 planets around pulsar PSR B1257+12 fit with the predictions with a relative accuracy of few hours/per several months. Also predictions for the distribution of stars in the regions where morphogenesis occurs follow from the gravitational Schrödinger equation.

What is important is that there are no free parameters besides v_0 . In [2] a wide variety of astrophysical data is discussed and it seem that the model works and has already now made predictions which have been later verified.

1.2 Quantization of Planck constant

In TGD framework [TGDview] the idea about quantized Planck constant emerged originally from a TGD inspired model of topological quantum computation [E9]. Large values of Planck constant would scale up quantal time and length scales and make possible macroscopic quantum phases and thus provide the new physics crucial for quantum models of living matter and conscious brain.

1.2.1 Dark matter as macroscopic quantum phase with a gigantic value of Planck constant

Learning about evidence for Bohr quantization of planetary orbits based on a gigantic value of gravitational constant [2, 3] led to the idea that the Bohr orbitology for visible matter might reflect the presence of dark matter characterized by gigantic values of Planck constant and thus in "astroscopic" quantum phase. In a strong contrast with the top-down approach of M-theory, the road to quantum gravity might mimic the much more modest approach leading from hydrogen atom to QED. Just as the Bohr model for hydrogen atom resolved the infrared catastrophe (electron falling into nucleus by emission of radiation), the Bohr model for planetary system could prevent collapse of matter to black hole.

1.2.2 Quantization of Planck constants and hyper-finite factors of type II_1

The infinite-dimensional Clifford algebra of the configuration space of 3-surfaces ("world of classical worlds") corresponds to von Neumann algebra known as hyperfinite factor of type II_1 . The so called Jones inclusions for these algebras led via a sequence of educated guess to the recent proposal for the quantization of Planck constants associated with symmetry algebras of M^4 and CP_2 as integer multiples $\hbar(M^4) = n_a \hbar_0$ and $\hbar(CP_2) = n_b \hbar_0$ of the minimal value \hbar_0 of Planck constant. n_a and n_b correspond to orders of maximal cyclic subgroups for the discrete subgroups of $SU(2)$ characterizing these inclusions and the formula follows using anyonic arguments.

A considerable generalization of the notion of imbedding space emerged and a concrete geometric and topological interpretation for how quantum groups characterized by phases $q_i = \exp(i\pi/n_i)$, $i = 1, b$ are realized in physics. This implies also a model for phase transitions changing the values of Planck constants as a complete or partial leakage of particle 3-surfaces between different sectors of generalized imbedding spaces obtained by gluing together various copies of imbedding space together along common M^4 or CP_2 factor. One can say that two levels of hierarchy are dark relative to each other if they correspond to a different sector of imbedding space.

The basic prediction is that ordinary Planck constant \hbar appearing in the Schrödinger equation can be expressed as $\hbar/\hbar_0 = \hbar(M^4)/\hbar(CP_2) = n_a/n_b$ and can in principle have all rational values. Number theoretic considerations however favor what might be called ruler and compass rationals for which n_a and n_b define n-polygons constructible using only ruler and com-

pass (the corresponding quantum phases are obtained by iterated square root operation from rationals).

Quantization of Planck constants is equivalent with the scaling of covariant metrics of M^4 resp. CP_2 by factor n_b^2 resp. n_a^2 followed by over-all scaling by factor $1/n_a^2$ leaving Kähler action invariant. Hence CP_2 metric remains invariant, and one avoids mathematical difficulties in gluing of various copies of the imbedding space together isometrically. M^4 covariant metric is scaled by $(n_b/n_a)^2$ meaning that effective Planck constant appearing in Schrödinger equation is $(n_a/n_b)\hbar_0$. In this interpretation scaling of Planck constants has a purely geometric meaning.

1.3 The evolution of the model for planetary system

A brief summary about the evolution of the model for planetary system is in order.

1.3.1 Understanding the value of the parameter v_0

The first observation was that TGD allows to understand the value of the parameter v_0/c assuming that cosmic strings and their decay remnants are responsible for the dark matter. The number theoretically preferred prediction would be $v_0 = 2^{-11}$ and expressible in terms of fundamental constants of quantum TGD (Planck length, CP_2 radius, and Kähler coupling strength).

The harmonics of v_0 could be understood as corresponding to perturbations replacing cosmic strings with their n -branched coverings so that tension becomes n^2 -fold: much like the replacement of a closed orbit with an orbit closing only after n turns. $1/n$ -sub-harmonic would result when a magnetic flux tube split into n disjoint magnetic flux tubes. Also rational multiples of v_0 are possible if both mechanisms operate.

The general formula for \hbar_{gr}/\hbar_0 as ruler and compass rational allowed a more precise prediction for v_0 and led also to a prediction for the ratios of planetary masses as ratios of ruler and compass rationals.

Later a possible interpretation of v_0 as a reduced light velocity emerged. The reduction would be due to the warping of dark space-time sheets meaning that the time component of the induced metric is reduced and one can identify a possible mechanism leading to the warping in the phase transition increasing Planck constant. This effect implies also time dilatation and distinguishes between TGD and General Relativity. These two explanations need not be mutually exclusive.

1.3.2 View about evolution of planetary system

The study of inclinations (tilt angles with respect to the Earth's orbital plane) leads to a concrete model for the quantum evolution of the planetary system. Only a stepwise breaking of the rotational symmetry and angular momentum Bohr rules plus Newton's equation (or geodesic equation) are needed, and gravitational Schrödinger equation holds true only inside flux quanta for the dark matter.

a) During pre-planetary period dark matter formed a quantum coherent state on the (Z^0) magnetic flux quanta (spherical cells or flux tubes). This made the flux quantum effectively a single rigid body with rotational degrees of freedom corresponding to a sphere or circle (full $SO(3)$ or $SO(2)$ symmetry).

b) In the case of spherical shells associated with inner planets the $SO(3) \rightarrow SO(2)$ symmetry breaking led to the generation of a flux tube with the inclination determined by m and j and a further symmetry breaking, kind of an astral traffic jam inside the flux tube, generated a planet moving inside flux tube. The semiclassical interpretation of the angular momentum algebra predicts the inclinations of the inner planets. The predicted (real) inclinations are 6 (7) resp. 2.6 (3.4) degrees for Mercury resp. Venus). The predicted (real) inclination of the Earth's spin axis is 24 (23.5) degrees.

c) The $v_0 \rightarrow v_0/5$ transition allowing to understand the radii of the outer planets in the model of Da Rocha and Nottale could be understood as resulting from the splitting of (Z^0 and gravi-) magnetic flux tube to five flux tubes representing Earth and outer planets except Pluto, whose orbital parameters indeed differ dramatically from those of other planets. The flux tube has a shape of a disk with a hole glued to the Earth's spherical flux shell.

It is important to notice that effectively a multiplication $n \rightarrow 5n$ of the principal quantum number is in question. This allows to consider also alternative explanations. Perhaps external gravitational perturbations have kicked dark matter from the orbit or Earth to $n = 5k$, $k = 2, 3, \dots, 7$ orbits: the fact that the tilt angles for Earth and all outer planets except Pluto (not a planet anymore!) are nearly the same, supports this explanation. Or perhaps there exist at least small amounts of dark matter at all orbits but visible matter is concentrated only around orbits containing some critical amount of dark matter and these orbits satisfy $n \bmod 5 = 0$ for some reason. TGD based explanation for so called flyby anomaly [6] is based on this assumption [D6].

The rather amazing coincidences between basic bio-rhythms and the pe-

riods associated with the states of orbits in solar system [D6] suggest that the frequencies defined by the energy levels of the gravitational Schrödinger equation might entrain with various biological frequencies such as the cyclotron frequencies associated with the magnetic flux tubes. For instance, the period associated with $n = 1$ orbit in the case of Sun is 24 hours within experimental accuracy for v_0 .

1.3.3 Improved predictions for planetary radii and predictions for ratios of planetary masses

The general prediction for the spectrum of \hbar as ruler and compass rational gives strong additional constraints but also flexibility since $\hbar_{gr} = GMm/v_0$ can correspond to ruler and compass integer. The planetary mass ratios can be produced with an accuracy better than 2 per cent assuming that \hbar_{gr}/\hbar_0 is ruler and compass rational.

Ruler and compass hypothesis for allows to improve the fit for the planetary radii in solar system. Also the radii of exoplanets can be fitted with few per cent accuracy (see the section "Orbital radii of exoplanets" and the tables of the Appendix). One cannot hope much more since star masses are deduced theoretically. Moreover the ratios of planetary masses are predicted to be expressible as ratios of ruler and compass rationals and this turns out to be true with 2 per cent accuracy (Table 2). Hence it seems that the hypothesis deserves to be taken seriously. One can even consider the possibility of deducing masses of stars from the orbital radii of exoplanets so that stars models could be tested.

To sum up, it would be too early to say that the proposed model has reached its final form but already at this stage a rich spectrum of predictions follows. It is probably needless to add that the existence of the proposed dark matter hierarchy means that a new period of voyages of discovery to the levels of existence responsible for the special properties of living systems would be waiting for us.

2 Dark matter hierarchy and quantization of Planck constants

In this section the quantization of Planck constants in TGD framework is briefly discussed. The detailed discussion can be found in [A9].

The recent geometric interpretation for the quantization of Planck constants is based on Jones inclusions of hyper-finite factors of type II_1 [A9].

a) One can argue that different values of Planck constant correspond to imbedding space metrics involving scalings of M^4 resp. CP_2 parts of the metric deduced from the requirement that distances scale as $\hbar(CP_2)$ resp. $\hbar(M^4)$. Denoting the Planck constants by $\hbar(M^4) = n_a \hbar_0$ and $\hbar(CP_2) = n_b \hbar_0$, one has that covariant metric of M^4 is proportional to n_b^2 and covariant metric of CP_2 to n_a^2 .

This however leads to difficulties with the isometric gluing of CP_2 factors of different copies of H together. Kähler action is however invariant under over-all scaling of H metric so that one can scale it down by $1/n_a^2$ meaning that M^4 covariant metric is scaled by $(n_b/n_a)^2$ and CP_2 metric remains invariant and the difficulties in isometric gluing are avoided. This means that if one regards Planck constant as a mere conversion factor, the effective Planck constant scales as n_a/n_b and Planck constant has a purely geometric meaning as scaling factor of M^4 metric.

In Kähler action only the effective Planck constant $\hbar_{eff}/\hbar_0 = \hbar(M^4)/\hbar(CP_2)$ appears and by quantum classical correspondence same is true for Schrödinger equation. Elementary particle mass spectrum is also invariant. Same applies to gravitational constant. The alternative assumption that M^4 Planck constant is proportional to n_b would imply invariance of Schrödinger equation but would not allow to explain Bohr quantization of planetary orbits and would to certain degree trivialize the theory.

b) M^4 and CP_2 Planck constants do not fully characterize a given sector $M^4_{\pm} \times CP_2$. Rather, the scaling factors of Planck constant given by the integer n characterizing the quantum phase $q = \exp(i\pi/n)$ corresponds to the order of the maximal cyclic subgroup for the group $G \subset SU(2)$ characterizing the Jones inclusion $\mathcal{N} \subset \mathcal{M}$ of hyper-finite factors realized as subalgebras of the Clifford algebra of the "world of the classical worlds". This means that subfactor \mathcal{N} gives rise to G -invariant configuration space spinors having interpretation as G -invariant fermionic states.

c) $G_b \subset SU(2) \subset SU(3)$ defines a covering of M^4_{\pm} by CP_2 points and $G_a \subset SU(2) \subset SL(2, C)$ covering of CP_2 by M^4_{\pm} points with fixed points defining orbifold singularities. Different sectors are glued isometrically together along CP_2 if G_b is same for them and along M^4_{\pm} if G_a is same for them. The degrees of freedom lost by G -invariance in fermionic degrees of freedom are gained back since the discrete degrees of freedom provided by covering allow many-particle states formed from single particle states realized in G group algebra. Among other things these many-particle states make possible the notion of N-atom.

d) Phases with different values of scalings of M^4 and CP_2 Planck constants behave like dark matter with respect to each other in the sense that

they do not have direct interactions except at criticality corresponding to a leakage between different sectors of imbedding space glued together along M^4 or CP_2 factors. In large $\hbar(M^4)$ phases various quantum time and length scales are scaled up which means macroscopic and macro-temporal quantum coherence. In particular, quantum energies associated with classical frequencies are scaled up by a factor n_a/n_b which is of special relevance for cyclotron energies and phonon energies (superconductivity). For large $\hbar(CP_2)$ the value of \hbar_{eff} is small: this leads to interesting physics: in particular the binding energy scale of hydrogen atom increases by the factor $(n_b/n_a)^2$.

2.1 Generalization of the p-adic length scale hypothesis and preferred values of Planck constants

The evolution in phase resolution in p-adic degrees of freedom corresponds to emergence of algebraic extensions allowing increasing variety of phases $exp(i\pi/n)$ expressible p-adically. This evolution can be assigned to the emergence of increasingly complex quantum phases and the increase of Planck constant.

One expects that quantum phases $q = exp(i\pi/n)$ which are expressible using only iterated square root operation are number theoretically very special since they correspond to algebraic extensions of p-adic numbers obtained by an iterated square root operation, which should emerge first. Therefore systems involving these values of q should be especially abundant in Nature.

These polygons are obtained by ruler and compass construction and Gauss showed that these polygons, which could be called Fermat polygons, have $n_F = 2^k \prod_s F_{n_s}$ sides/vertices: all Fermat primes F_{n_s} in this expression must be different. The analog of the p-adic length scale hypothesis emerges since larger Fermat primes are near a power of 2. The known Fermat primes $F_n = 2^{2^n} + 1$ correspond to $n = 0, 1, 2, 3, 4$ with $F_0 = 3$, $F_1 = 5$, $F_2 = 17$, $F_3 = 257$, $F_4 = 65537$. It is not known whether there are higher Fermat primes. $n = 3, 5, 15$ -multiples of p-adic length scales clearly distinguishable from them are also predicted and this prediction is testable in living matter. I have already earlier considered the possibility that Fermat polygons could be of special importance for cognition and for biological information processing [H8].

This condition could be interpreted as a kind of resonance condition guaranteing that scaled up sizes for space-time sheets have sizes given by p-adic length scales. The numbers n_F could take the same role in the evolution of Planck constant assignable with the phase resolution as Mersenne primes

have in the evolution assignable to the p-adic length scale resolution.

2.2 How Planck constants are visible in Kähler action?

$\hbar(M^4)$ and $\hbar(CP_2)$ appear in the commutation and anticommutation relations of various superconformal algebras. Only the ratio n_a/n_b of M^4 and CP_2 Planck constants appears in Kähler action. This implies that Kähler function codes for radiative corrections to the classical action, which makes possible to consider the possibility that higher order radiative corrections to functional integral vanish as one might expect at quantum criticality. For a given p-adic length scale space-time sheets with all allowed values of Planck constants are possible. Hence the spectrum of quantum critical fluctuations could in the ideal case correspond to the spectrum of \hbar coding for the scaled up values of Compton lengths and other quantal lengths and times. If so, large \hbar phases could be crucial for understanding of quantum critical superconductors, in particular high T_c superconductors.

2.3 Phase transitions changing the level in dark matter hierarchy

The identification of the precise criterion characterizing dark matter phase is far from obvious. TGD actually suggests an infinite number of phases which are dark relative to each other in some sense and can transform to each other only via a phase transition which might be called de-coherence or its reversal and which should be also characterized precisely.

A possible solution of the problem comes from the general construction recipe for S-matrix. Fundamental vertices correspond to partonic 2-surfaces representing intersections of incoming and outgoing light-like partonic 3-surfaces.

a) If the characterization of the interaction vertices involves all points of partonic 2-surfaces, they must correspond to definite value of Planck constant and more precisely, definite groups G_a and G_b characterizing dark matter hierarchy. Particles of different phases could not appear in the same vertex and a phase transition changing the particles to each other analogous to a de-coherence would be necessary.

b) If transition amplitudes involve only a discrete set of common orbifold points of 2-surface belonging to different sectors then the phase transition between relatively dark matters can be described in terms of S-matrix. It seems that this option is the correct one. In fact, also propagators are essential for the interactions of visible and dark matter and since virtual

elementary particles correspond at space-time level CP_2 type extremals with 4-dimensional CP_2 projection, they cannot leak between different sectors of imbedding space and therefore cannot mediate interactions between different levels of the dark matter hierarchy. This would suggest that the direct interactions between dark and ordinary matter are very weak.

If the matrix elements for real-real partonic transitions involve all or at least a circle of the partonic 2-surface as stringy considerations suggest [C2], then one would have clear distinction between quantum phase transitions and ordinary quantum transitions. Of course, the fact that the points which correspond to zero of Riemann Zeta form only a small subset of points common to real partonic 2-surface and corresponding p-adic 2-surface, implies that the rate for phase transition is in general small. On the other hand, for the non-diagonal S-matrix elements for ordinary transitions would become very small by almost randomness caused by strong fluctuations and the rate for phase transition could begin to dominate.

3 Some astrophysical applications

There is considerable support for the Bohr quantization of planetary orbits both in solar system and from exoplanets. The needed gigantic values of gravitational Planck constant can be understood in TGD framework and assigned to dark matter. Theory also predicts preferred ratios for planetary masses and provides a possible interpretation for the velocity parameter characterizing \hbar_{gr} . The interpretation of the symmetry group Z_n associated with dark matter can be assigned as broken rotational symmetries of the gravi-magnetic and electric bodies mediating interaction between star and planet. Tifft's quantization of cosmic redshifts can be also understand in this framework. A thorough discussion of this subject can be found at [D6]. Here only a brief summary is given.

3.1 Bohr quantization of planetary orbits and preferred values of Planck constant

The predictions of the generalization of the p-adic length scale hypothesis are consistent with the TGD based model for the Bohr quantization of planetary orbits and some new non-trivial predictions follow.

Since the macroscopic quantum phases with minimum dimension of algebraic extension should be especially abundant in the universe, the natural guess is that the values of the gravitational Planck constant correspond to n_F -multiples of ordinary Planck constant.

a) The model can explain the enormous values of gravitational Planck constant $\hbar_{gr}/\hbar_0 = \simeq GMm/v_0 = n_a/n_b$. The favored values of this parameter should correspond to n_{F_a}/n_{F_b} so that the mass ratios $m_1/m_2 = n_{F_{a,1}}n_{F_{b,2}}/n_{F_{b,1}}n_{F_{a,2}}$ for planetary masses should be preferred. The general prediction $GMm/v_0 = n_a/n_b$ is of course not testable.

b) Nottale [2] has suggested that also the harmonics and subharmonics of λ are possible and in fact required by the model for planetary Bohr orbits (in TGD framework this is not absolutely necessary). The prediction is that favored values of n should be of form $n_F = 2^k \prod F_i$ such that F_i appears at most once. In Nottale's model for planetary orbits as Bohr orbits in solar system $n = 5$ harmonics appear and are consistent with either $n_{F,a} \rightarrow F_1 n_{F_a}$ or with $n_{F,b} \rightarrow n_{F_b}/F_1$ if possible.

	T-B	Bohr _a	Bohr _b	Bohr _c
Planet	R_{pr}/R	$[n, R_{pr}/R]$	$[n, R_{pr}/R]$	$[r/s, R_{pr}/R]$
Mercury	1	[3, 1]	[3, 1]	[1,1]
Venus	.93	[4, .95]	[4, .95]	[1,.95]
Earth	.96	[5, 1.08]	[5, 1.08]	[1,1.08]
Mars	1.03	[6, 1.03]	[6, 1.03]	[1,1.03]
Jupiter	.95	[11, .98]	$[2 \times 5, .81]$	[17/15,1.04]
Saturn	1.00	$[3 \times 5, 1.00]$	$[3 \times 5, 1.00]$	[1,1.00]
Uranus	.95	[22, 1.04]	$[4 \times 5, .86]$	[16/15,.98]
Neptune	1.23	[27, 1.03]	$[5 \times 5, .88]$	[17/16,.99]
Pluto	.92	[31, 1.01]	$[6 \times 5, .95]$	[1,.95]

Table 1. The table represents the ratios R_{pr}/R of predictions R_{pr} of various models for orbital radii to their experimental average values R . The first column represents Titius-Bode law (T-B in table). The remaining columns represent variants of Bohr orbit model assuming a) that the principal quantum number n corresponds to the best possible fit and v_0 has single value, b) assuming the scaling $v_0 \rightarrow v_0/5$ for outer planets, c) assuming besides $v_0 \rightarrow v_0/5$ the modification $v_0 \rightarrow (r/s)v_0$, where r/s is ruler and compass rational. The scaling of v_0 is chosen to give complete fit for Mercury.

Table 1 gives the radii of planet for Titius-Bode law and various Bohr orbit models. Not surprisingly, option a) gives the best fit with errors being considerably smaller than the maximal error $|\Delta R|/R \simeq 1/n$ except for Uranus. The fit given by option b) is poor for Jupiter, Uranus and Saturnus but improves for option c).

The prediction for the ratios of planetary masses can be tested. In the table below are the experimental mass ratios $r_{exp} = m(pl)/m(E)$, the best choice of $r_R = [n_{F,a}/n_{F,b}] * X$, X common factor for all planets, and the ratios $r_{pred}/r_{exp} = n_{F,a}(planet)n_{F,b}(Earth)/n_{F,a}(Earth)n_{F,b}(planet)$. The deviations are at most 2 per cent.

<i>planet</i>	<i>Me</i>	<i>V</i>	<i>E</i>	<i>M</i>	<i>J</i>
<i>y</i>	$\frac{2^{13} \times 5}{17}$	$2^{11} \times 17$	$2^9 \times 5 \times 17$	$2^8 \times 17$	$\frac{2^{23} \times 5}{7}$
<i>y/x</i>	1.01	.98	1.00	.98	1.01
<i>planet</i>	<i>S</i>	<i>U</i>	<i>N</i>	<i>P</i>	
<i>y</i>	$2^{14} \times 3 \times 5 \times 17$	$\frac{2^{21} \times 5}{17}$	$\frac{2^{17} \times 17}{3}$	$\frac{2^4 \times 17}{3}$	
<i>y/x</i>	1.01	.98	.99	.99	

Table 2. The table compares the ratios $x = m(pl)/(m(E))$ of planetary mass to the mass of Earth to prediction for these ratios in terms of integers n_F associated with Fermat polygons. y gives the best fit for the allowed factors of the known part y of the rational $n_{F,a}/n_{F,b} = yX$ characterizing planet, and the ratios y/x . Errors are at most 2 per cent.

3.2 Orbital radii of exoplanets

Orbital radii of exoplanets serve as a test for the quantization hypothesis. Hundreds of them are already known and in [4] tables listing basic data for for more than one hundred exoplanets can be found. Tables of Appendix provide also references and links to sources giving data about stars, in particular star mass M using solar mass M_S as a unit. Hence one can test the formula for the orbital radii given by the expression

$$\frac{r}{r_E} = \frac{n^2}{5^2} \frac{M}{M_S} X . \quad (1)$$

Here the correction factor X depends on the model.

a) $X = 1$ corresponds to the prediction of the simplest model allowing only single value of v_0 . It turns out that the simplest option assuming $X = 1$ fails badly for some planets: the resulting deviations of order 20 per cent typically but in the worst cases the predicted radius is by factor of $\sim .5$ too small.

b) Nottale [2] has proposed that it is possible to improve the situation by allowing harmonics and sub-harmonics of v_0 which would mean $X = n^2$

or $1/n^2$.

c) In TGD framework general quantization of Planck constant allows X to be any rational but number theoretical arguments prefer the values of X which are squares of "ruler and compass" rationals:

$$\begin{aligned} X &= \left(\frac{n_1}{n_2}\right)^2, \\ n_i &= 2^{k_i} \times \prod_{s_i} F_{s_i}, \quad F_{s_i} \in \{3, 5, 17, 257, 2^{16} + 1\}. \end{aligned} \quad (2)$$

Here a given Fermat prime F_{s_i} can appear only once.

The values of X used in the fit correspond to $X \in \{(2/3)^2, (3/4)^2, (4/5)^2, (5/6)^2, (15/17)^2, (15/16)^2, (16/17)^2\} \simeq \{.44, .56, .64, .69, .78, .88, .89\}$ and their inverses. The tables summarizing the resulting fit using both $X = 1$ and value giving optimal fit are given in the Appendix. The deviations are typically few per cent and one must also take into account the fact that the masses of stars are deduced theoretically using the spectral data from star models. I am not able to form an opinion about the real error bars related to the masses.

3.3 A more detailed model for planetary system

The Bohr orbit model for planetary system leads to the idea that the evolution of planetary system could be understood in terms of dark matter. One can also ask whether the inclinations and eccentricities of planetary orbits could be deduced from Bohr orbitology.

3.3.1 The interpretation of \hbar_{gr} and pre-planetary period

\hbar_{gr} could corresponds to a unit of angular momentum for quantum coherent states at magnetic flux tubes or walls containing macroscopic quantum states. Quantitative estimate demonstrates that \hbar_{gr} for astrophysical objects cannot correspond to spin angular momentum. For Sun-Earth system one would have $\hbar_{gr} \simeq 10^{77} \hbar$. This amount of angular momentum realized as a mere spin would require 10^{77} particles! Hence the only possible interpretation is as a unit of orbital angular momentum. The linear dependence of \hbar_{gr} on m is consistent with the additivity of angular momenta in the fusion of magnetic flux tubes to larger units if the angular momentum associated with the tubes is proportional to both m and M .

Just as the gravitational acceleration is a more natural concept than gravitational force, also $\hbar_{gr}/m = GM/v_0$ could be more natural unit than

\hbar_{gr} . It would define a universal unit for the circulation $\oint v \cdot dl$, which is apart from $1/m$ -factor equal to the phase integral $\oint p_\phi d\phi$ appearing in Bohr rules for angular momentum. The circulation could be associated with the flow associated with outer boundaries of magnetic flux tubes surrounding the orbit of mass m around the central mass $M \gg m$ and defining light like 3-D CDs analogous to black hole horizons.

The expression of \hbar_{gr} depends on masses M and m and can apply only in space-time regions carrying information about the space-time sheets of M and the orbit of m . Quantum gravitational holography suggests that the formula applies at 3-D light like causal determinant (CD) X_l^3 defined by the wormhole contacts gluing the space-time sheet X_l^3 of the planet to that of Sun. More generally, X_l^3 could be the space-time sheet containing the planet, most naturally the magnetic flux tube surrounding the orbit of the planet and possibly containing dark matter in super-conducting state. This would give a precise meaning for \hbar_{gr} and explain why \hbar_{gr} does not depend on the masses of other planets.

The simplest option consistent with the quantization rules and with the explanatory role of magnetic flux structures is perhaps the following one.

a) X_l^3 is a torus like surface around the orbit of the planet containing delocalized dark matter. The key role of magnetic flux quantization in understanding the values of v_0 suggests the interpretation of the torus as a magnetic or Z^0 magnetic flux tube. At pre-planetary period the dark matter formed a torus like quantum object. The conditions defining the radii of Bohr orbits follow from the requirement that the torus-like object is in an eigen state of angular momentum in the center of mass rotational degrees of freedom. The requirement that rotations do not leave the torus-like object invariant is obviously satisfied. Newton's law required by the quantum-classical correspondence stating that the orbit corresponds to a geodesic line in general relativistic framework gives the additional condition implying Bohr quantization.

b) A simple mechanism leading to the localization of the matter would have been the pinching of the torus causing kind of a traffic jam leading to the formation of the planet. This process could quite well have involved a flow of matter to a smaller planet space-time sheet Y_l^3 topologically condensed at X_l^3 . Most of the angular momentum associated with torus like object would have transformed to that of planet and situation would have become effectively classical.

c) The conservation of magnetic flux means that the splitting of the orbital torus would generate a pair of Kähler magnetic charges. It is not clear whether this is possible dynamically and hence the torus could still

be there. In fact, TGD explanation for the tritium beta decay anomaly citeTroitsk,Mainz in terms of classical Z^0 force [F8] requires the existence of this kind of torus containing neutrino cloud whose density varies along the torus. This picture suggests that the lacking $n = 1$ and $n = 2$ orbits in the region between Sun and Mercury are still in magnetic flux tube state containing mostly dark matter.

d) The fact that \hbar_{gr} is proportional to m means that it could have varied continuously during the accumulation of the planetary mass without any effect in the planetary motion: this is of course nothing but a manifestation of Equivalence Principle.

e) It is interesting to look for the scaled up versions of Planck mass $m_{Pl} = \sqrt{\hbar_{gr}/\hbar} \times \sqrt{\hbar/G} = \sqrt{M_1 M_2 / v_0}$ and Planck length $L_{Pl} = \sqrt{\hbar_{gr}/\hbar} \times \sqrt{\hbar/G} = G \sqrt{M_1 M_2 / v_0}$. For $M_1 = M_2 = M$ this gives $m_{Pl} = M/\sqrt{v_0} \simeq 45.6 \times M$ and $L_{Pl} = r_S/2\sqrt{v_0} \simeq 22.8 \times r_S$, where r_S is Schwartzchild radius. For Sun r_S is about 2.9 km so that one has $L_{Pl} \simeq 66$ km. For a few years ago it was found that Sun contains "inner-inner" core of radius about $R = 300$ km [11] which is about $4.5 \times L_{Pl}$.

3.3.2 Inclinations for the planetary orbits and the quantum evolution of the planetary system

The inclinations of planetary orbits provide a test bed for the theory. The semiclassical quantization of angular momentum gives the directions of angular momentum from the formula

$$\cos(\theta) = \frac{m}{\sqrt{j(j+1)}} , \quad |m| \leq j . \quad (3)$$

where θ is the angle between angular momentum and quantization axis and thus also that between orbital plane and (x,y)-plane. This angle defines the angle of tilt between the orbital plane and (x,y)-plane.

$m = j = n$ gives minimal value of angle of tilt for a given value of n of the principal quantum number as

$$\cos(\theta) = \frac{n}{\sqrt{n(n+1)}} . \quad (4)$$

For $n = 3, 4, 5$ (Mercury, Venus, Earth) this gives $\theta = 30.0, 26.6,$ and 24.0 degrees respectively.

Only the relative tilt angles can be compared with the experimental data. Taking as usual the Earth's orbital plane as the reference the relative tilt angles give what are known as inclinations. The predicted inclinations are 6 degrees for Mercury and 2.6 degrees for Venus. The observed values [12] are 7.0 and 3.4 degrees so that the agreement is satisfactory. If one allows half-odd integer spin the fit is improved. For $j = m = n - 1/2$ the predictions are 7.1 and 2.9 degrees for Mercury and Venus respectively. For Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto the inclinations are 1.9, 1.3, 2.5, 0.8, 1.8, 17.1 degrees. For Mars and outer planets the tilt angles are predicted to have wrong sign for $m = j$. In a good approximation the inclinations vanish for outer planets except Pluto and this would allow to determine m as $m \simeq \sqrt{5n(n+1)}/6$: the fit is not good.

The assumption that matter has condensed from a matter rotating in (x,y)-plane orthogonal to the quantization axis suggests that the directions of the planetary rotation axes are more or less the same and by angular momentum conservation have not changed appreciably. The prediction for the tilt of the rotation axis of the Earth is 24 degrees of freedom in the limit that the Earth's spin can be treated completely classically, that is for $m = j \gg 1$ in the units used for the quantization of the Earth's angular momentum. What is the value of \hbar_{gr} for Earth is not obvious (using the unit $\hbar_{gr} = GM^2/v_0$ the Earth's angular momentum would be much smaller than one). The tilt of the rotation axis of Earth with respect to the orbit plane is 23.5 degrees so that the agreement is again satisfactory. This prediction is essentially quantal: in purely classical theory the most natural guess for the tilt angle for planetary spins is 0 degrees.

The observation that the inner planets Mercury, Venus, and Earth have in a reasonable approximation the predicted inclinations suggest that they originate from a primordial period during which they formed spherical cells of dark matter and had thus full rotational degrees of freedom and were in eigen states of angular momentum corresponding to a full rotational symmetry. The subsequent $SO(3) \rightarrow SO(2)$ symmetry breaking leading to the formation of torus like configurations did not destroy the information about this period since the information about the value of j and m was coded by the inclination of the planetary orbit.

In contrast to this, the dark matter associated with Earth and outer planets up to Neptune formed a flattened magnetic or Z^0 magnetic flux tube resembling a disk with a hole and the subsequent symmetry breaking broke it to separate flux tubes. Earth's spherical disk was joined to the disk formed by the outer planets. The spherical disk could be still present and contain super-conducting dark matter. The presence of this "heavenly sphere" might

closely relate to the fact that Earth is a living planet. The time scale $T = 2\pi R/c$ is very nearly equal to 5 minutes and defines a candidate for a bio-rhythm.

If this flux tube carried the same magnetic flux as the flux tubes associated with the inner planets, the decomposition of the disk with a hole to 5 flux tubes corresponding to Earth and to the outer planets Mars, Jupiter, Saturn and Neptune, would explain the value of v_0 correctly and also the small inclinations of outer planets. That Pluto would not originate from this structure, is consistent with its anomalously large values of inclination $i = 17.1$ degrees, small value of eccentricity $e = .248$, and anomalously large value of inclination of equator to orbit about 122 degrees as compared to 23.5 degrees in the case of Earth [12].

3.3.3 Eccentricities and comets

Bohr-Sommerfeld quantization allows also to deduce the eccentricities of the planetary and comet orbits. One can write the quantization of energy as

$$\frac{p_r^2}{2m_1} + \frac{p_\theta^2}{2m_1 r^2} + \frac{p_\phi^2}{2m_1 r^2 \sin^2(\theta)} - \frac{k}{r} = -\frac{E_1}{n^2} ,$$

$$E_1 = \frac{k^2}{2\hbar_{gr}^2} \times m_1 = \frac{v_0^2}{2} \times m_1 . \quad (5)$$

Here one has $k = GMm_1$. E_1 is the binding energy of $n = 1$ state. In the orbital plane ($\theta = \pi/2, p_\theta = 0$) the conditions are simplified. Bohr quantization gives $p_\phi = m\hbar_{gr}$ implying

$$\frac{p_r^2}{2m_1} + \frac{k^2 \hbar_{gr}^2}{2m_1 r^2} - \frac{k}{r} = -\frac{E_1}{n^2} . \quad (6)$$

For $p_r = 0$ the formula gives maximum and minimum radii r_\pm and eccentricity is given by

$$e^2 = \frac{r_+ - r_-}{r_+} = \frac{2\sqrt{1 - \frac{m^2}{n^2}}}{1 + \sqrt{1 - \frac{m^2}{n^2}}} . \quad (7)$$

For small values of n the eccentricities are very large except for $m = n$. For instance, for $(m = n - 1, n)$ for $n = 3, 4, 5$ gives $e = (.93, .89, .86)$

to be compared with the experimental values (.206, .007, .0167). Thus the planetary eccentricities with Pluto included ($e = .248$) must vanish in the lowest order approximation and must result as a perturbation of the magnetic flux tube.

The large eccentricities of comet orbits might however have an interpretation in terms of $m < n$ states. The prediction is that comets with small eccentricities have very large orbital radius. Oort's cloud is a system weakly bound to a solar system extending up to 3 light years. This gives the upper bound $n \leq 700$ if the comets of the cloud belong to the same family as Mercury, otherwise the bound is smaller. This gives a lower bound to the eccentricity of not nearly circular orbits in the Oort cloud as $e > .32$.

3.4 About the interpretation of the parameter v_0

The formula for the gravitational Planck constant contains the parameter $v_0/c = 2^{-11}$. This velocity defines the rotation velocities of distant stars around galaxies. The presence of a parameter with dimensions of velocity should carry some important information about the geometry of dark matter space-time sheets. The interpretation in terms of cosmic strings and magnetic flux tubes has been already discussed but also alternative interpretations can be considered.

Velocity like parameters appear also in other contexts. There is evidence for the Tifft's quantization of cosmic red-shifts in multiples of $v_0/c = 2.68 \times 10^{-5}/3$: also other units of quantization have been proposed but they are multiples of v_0 [5].

The strange behavior of graphene includes high conductivity with conduction electrons behaving like massless particles with light velocity replaced with $v_0/c = 1/300$. The TGD inspired model [J1] explains the high conductivity as being due to the Planck constant $\hbar(M^4) = 6\hbar_0$ increasing the delocalization length scale of electron pairs associated with hexagonal rings of mono-atomic graphene layer by a factor 6 and thus making possible overlap of electron orbitals. This explains also the anomalous conductivity of DNA containing 5- and 6-cycles [J1].

1. *Is dark matter warped?*

The reduced light velocity could be due to the warping of the space-time sheet associated with dark electrons. TGD predicts besides gravitational red-shift a non-gravitational red-shift due to the warping of space-time sheets possible because space-time is 4-surface rather than abstract 4-manifold. A simple example of everyday life is the warping of a paper sheet: it bends

but is not stretched, which means that the induced metric remains flat although one of its component scales (distance becomes longer along direction of bending). For instance, empty Minkowski space represented canonically as a surface of $M^4 \times CP_2$ with constant CP_2 coordinates can become periodically warped in time direction because of the bending in CP_2 direction. As a consequence, the distance in time direction shortens and effective light-velocity decreases when determined from the comparison of the time taken for signal to propagate from A to B along warped space-time sheet with propagation time along a non-warped space-time sheet.

The simplest warped imbedding defined by the map $M^4 \rightarrow S^1$, S^1 a geodesic circle of CP_2 . Let the angle coordinate of S^1 depend linearly on time: $\Phi = \omega t$. g_{tt} component of metric becomes $1 - R^2\omega^2$ so that the light velocity is reduced to $v_0/c = \sqrt{1 - R^2\omega^2}$. No gravitational field is present.

The fact that M^4 Planck constant $n_a\hbar_0$ defines the scaling factor n_a^2 of CP_2 metric could explain why dark matter resides around strongly warped imbeddings of M^4 . The quantization of the scaling factor of CP_2 by $R^2 \rightarrow n_a^2 R^2$ implies that the initial small warping in the time direction given by $g_{tt} = 1 - \epsilon$, $\epsilon = R^2\omega^2$, will be amplified to $g_{tt} = 1 - n_a^2\epsilon$ if ω is not affected in the transition to dark matter phase. $n_a = 6$ in the case of graphene would give $1 - x \simeq 1 - 1/36$ so that only a one per cent reduction of light velocity is enough to explain the strong reduction of light velocity for dark matter.

2. Is c/v_0 quantized in terms of ruler and compass rationals?

The known cases suggests that c/v_0 is always a rational number expressible as a ratio of integers associated with n-polygons constructible using only ruler and compass.

a) $c/v_0 = 300$ would explain graphene. The nearest rational satisfying the ruler and compass constraint would be $q = 5 \times 2^{10}/17 \simeq 301.18$.

b) If dark matter space-time sheets are warped with $c_0/v = 2^{11}$ one can understand Nottale's quantization for the radii of the inner planets. For dark matter space-time sheets associated with outer planets one would have $c/v_0 = 5 \times 2^{11}$.

c) If Tift's red-shifts relate to the warping of dark matter space-time sheets, warping would correspond to $v_0/c = 2.68 \times 10^{-5}/3$. $c/v_0 = 2^5 \times 17 \times 257/5$ holds true with an error smaller than .1 per cent.

3. Tift's quantization and cosmic quantum coherence

An explanation for Tift's quantization in terms of Jones inclusions could be that the subgroup G of Lorentz group defining the inclusion consists of boosts defined by multiples $\eta = n\eta_0$ of the hyperbolic angle $\eta_0 \simeq v_0/c$. This

would give $v/c = \sinh(n\eta_0) \simeq nv_0/c$. Thus the dark matter systems around which visible matter is condensed would be exact copies of each other in cosmic length scales since G would be an exact symmetry. The property of being an exact copy applies of course only in single level in the dark matter hierarchy. This would mean a delocalization of elementary particles in cosmological length scales made possible by the huge values of Planck constant. A precise cosmic analog for the delocalization of electron pairs in benzene ring would be in question.

Why then η_0 should be quantized as ruler and compass rationals? In the case of Planck constants the quantum phases $q = \exp(im\pi/n_F)$ are number theoretically simple for n_F a ruler and compass integer. If the boost $\exp(\eta)$ is represented as a unitary phase $\exp(im\eta)$ at the level of discretely delocalized dark matter wave functions, the quantization $\eta_0 = n/n_F$ would give rise to number theoretically simple phases. Note that this quantization is more general than $\eta_0 = n_{F,1}/n_{F,2}$.

The interpretation in terms of warping would suggest that the dark matter associated with distant stars in the galactic halos moves with a reduced light velocity in a state similar to that of conduction electrons in graphene. The consistency with the interpretation based on magnetic flux quanta remains open.

3.5 How do the magnetic flux tube structures and quantum gravitational bound states relate?

In the case of stars in galactic halo the appearance of the parameter v_0 characterizing cosmic strings as orbital rotation velocity can be understood classically. That v_0 appears also in the gravitational dynamics of planetary orbits could relate to the dark matter at magnetic flux tubes. The argument explaining the harmonics and sub-harmonics of v_0 in terms of properties of cosmic strings and magnetic flux tubes identifiable as their descendants strengthens this expectation. As a matter fact, magnetic body corresponds also to gravi-magnetic body since classical gauge fields and gravitational field are very closely related since CP_2 coordinates are primary dynamical variables.

3.5.1 The notion of field body

Topological field quantization implies that one can assign to a material system also field identity, field body. Field body contains both electric and magnetic part and consists of flux quanta of these fields identifiable as space-

time sheets. The notion of magnetic body plays a key role in TGD inspired theory of consciousness being the ultimate intentional agent, experiencer, and performer of bio-control and can have astrophysical size. This does not sound so counter-intuitive if one takes seriously the idea that cognition has p-adic space-time sheets as space-time correlates and that rational points are common to real and p-adic number fields. The point is that infinitesimal in p-adic topology corresponds to infinite in real sense so that cognitive and intentional structures would have literally infinite size.

The magnetic flux tubes carrying various supra phases can be interpreted as special instance of dark energy and dark matter. This suggests a correlation between gravitational self-organization and quantum phases at the magnetic flux tubes and that the gravitational Schrödinger equation somehow relates to the ordinary Schrödinger equation satisfied by the macroscopic quantum phases at magnetic flux tubes. In [A9] I have proposed that the transition increasing Planck constant occurs when perturbation theory fails and thus reduces the higher order radiative corrections. Interestingly, the transition to large Planck constant phase should occur when the masses of interacting is above Planck mass since gravitational self-interaction energy is $V \sim GM^2/R$. For the density of water about 10^3 kg/m^3 the volume carrying a Planck mass correspond to a cube with side 2.8×10^{-4} meters. This corresponds to a volume of a large neuron, which suggests that this phase transition might play an important role in neuronal dynamics.

3.5.2 G_a as a symmetry group of field body

The group $G_a \subset SU(2) \subset SL(2, C)$ appearing in the quantization of Planck constant, means exact rotational symmetry realized in terms of M_{\pm}^4 coverings of CP_2 . The 5- and 6-cycles in biochemistry (sugars, DNA,...) are excellent candidates for these symmetries. For very large values of Planck constant, say for the values $\hbar(M_{\pm}^4)/\hbar(CP_2) = GMm/v_0 = (n_a/n_b)\hbar_0$, $v_0 = 2^{-11}$, required by the model for planetary orbits as Bohr orbits [D6], G_a is huge and corresponds to either Z_{n_a} or in the case of even value of n_a to the group generated by Z_n and reflection acting on plane and containing $2n_a$ elements.

The notion of field body, in particular magnetic body, seems to provide the only conceivable candidate for a geometric object possessing G_a as symmetries. In the first approximation the magnetic field associated with a dark matter system is expected to be modellable as a dipole field having rotational symmetry around the dipole axis. Topological quantization means that this field decomposes into flux tube like structures related by the rotations of Z_n

or D_{2n} . Dark particles would have wave functions delocalized to this set of these flux quanta and span group algebra of G_a . Note that electric body as a structure consisting of radial electric flux tubes makes also sense and can possess G_a as a symmetry.

Magnetic and electric flux quanta would naturally mediate gravi-magnetic and -electric interactions in the TGD based model for the quantization of radii of planetary orbits and this explains the dependence of \hbar_{gr} on the masses of planet and central object [D6].

3.5.3 Could gravitational Schrödinger equation relate to a quantum control at magnetic flux tubes?

An infinite self hierarchy is the basic prediction of TGD inspired theory of consciousness ("everything is conscious and consciousness can be only lost"). Topological quantization allows to assign to any material system a field body as the topologically quantized field pattern created by the system [L4, K1]. This field body can have an astrophysical size and would utilize the material body as a sensory receptor and motor instrument.

Magnetic flux tube and flux wall structures are natural candidates for the field bodies. Various empirical inputs have led to the hypothesis that the magnetic flux tube structures define a hierarchy of magnetic bodies, and that even Earth and larger astrophysical systems possess magnetic body which makes them conscious self-organizing living systems. In particular, life at Earth would have developed first as a self-organization of the superconducting dark matter at magnetic flux tubes [L4].

For instance, EEG frequencies corresponds to wavelengths of order Earth size scale and the strange findings of Libet about time delays of conscious experience [13, 14] find an elegant explanation in terms of time taken for signals propagate from brain to the magnetic body [K1]. Cyclotron frequencies, various cavity frequencies, and the frequencies associated with various p-adic frequency scales are in a key role in the model of bio-control performed by the magnetic body. The cyclotron frequency scale is given by $f = eB/m$ and rather low as are also cavity frequencies such as Schumann frequencies: the lowest Schumann frequency is in a good approximation given by $f = 1/2\pi R$ for Earth and equals to 7.8 Hz.

1. Quantum time scales as "bio-rhythms" in solar system?

To get some idea about the possible connection of the quantum control possibly performed by the dark matter with gravitational Schrödinger equation, it is useful to look for the values of the periods defined by the

gravitational binding energies of test particles in the fields of Sun and Earth and look whether they correspond to some natural time scales. For instance, the period $T = 2GM_S n^2 / v_0^3$ defined by the energy of n^{th} planetary orbit depends only on the mass of Sun and defines thus an ideal candidate for a universal "bio-rhythm".

For Sun black hole radius is about 2.9 km. The period defined by the binding energy of lowest state in the gravitational field of Sun is given $T_S = 2GM_S / v_0^3$ and equals to 23.979 hours for $v_0/c = 4.8233 \times 10^{-4}$. Within experimental limits for v_0/c the prediction is consistent with 24 hours! The value of v_0 corresponding to exactly 24 hours would be $v_0 = 144.6578$ km/s (as a matter fact, the rotational period of Earth is 23.9345 hours). As if as the frequency defined by the lowest energy state would define a "biological" clock at Earth! Mars is now a strong candidate for a seat of life and the day in Mars lasts 24hr 37m 23s! $n = 1$ and $n = 2$ are orbitals are not realized in solar system as planets but there is evidence for the $n = 1$ orbital as being realized as a peak in the density of IR-dust [2]. One can of course consider the possibility that these levels are populated by small dark matter planets with matter at larger space-time sheets. Bet as it may, the result supports the notion of quantum gravitational entrainment in the solar system.

The slower rhythms would become as n^2 sub-harmonics of this time scale. Earth itself corresponds to $n = 5$ state and to a rhythm of .96 hours: perhaps the choice of 1 hour to serve as a fundamental time unit is not merely accidental. The magnetic field with a typical ionic cyclotron frequency around 24 hours would be very weak: for 10 Hz cyclotron frequency in Earth's magnetic field the field strength would about 10^{-11} T. However, $T = 24$ hours corresponds with 6 per cent accuracy to the p-adic time scale $T(k = 280) = 2^{13}T(2, 127)$, where $T(2, 127)$ corresponds to the secondary p-adic time scale of .1 s associated with the Mersenne prime $M_{127} = 2^{127} - 1$ characterizing electron and defining a fundamental bio-rhythm and the duration of memetic codon [TGDgame].

Comorosan effect [15, J5] demonstrates rather peculiar looking facts about the interaction of organic molecules with visible laser light at wavelength $\lambda = 546$ nm. As a result of irradiation molecules seem to undergo a transition $S \rightarrow S^*$. S^* state has anomalously long lifetime and stability in solution. $S \rightarrow S^*$ transition has been detected through the interaction of S^* molecules with different biological macromolecules, like enzymes and cellular receptors. Later Comorosan found that the effect occurs also in non-living matter. The basic time scale is $\tau = 5$ seconds. p-Adic length scale hypothesis does not explain τ , and it does not correspond to any obvious astrophysical time scale and has remained a mystery.

The idea about astro-quantal dark matter as a fundamental bio-controller inspires the guess that τ could correspond to some Bohr radius R for a solar system via the correspondence $\tau = R/c$. As observed by Nottale, $n = 1$ orbit for $v_0 \rightarrow 3v_0$ corresponds in a good approximation to the solar radius and to $\tau = 2.18$ seconds. For $v_0 \rightarrow 2v_0$ $n = 1$ orbit corresponds to $\tau = AU/(4 \times 25) = 4.992$ seconds: here $R = AU$ is the astronomical unit equal to the average distance of Earth from Sun. The deviation from τ_C is only one per cent and of the same order of magnitude as the variation of the radius for the orbit due to orbital eccentricity $(a - b)/a = .0167$ [12].

2. Earth-Moon system

For Earth serving as the central mass the Bohr radius is about 18.7 km, much smaller than Earth radius so that Moon would correspond to $n = 147.47$ for v_0 and $n = 1.02$ for the sub-harmonic $v_0/12$ of v_0 . For an aficionado of cosmic jokes or a numerologist the presence of the number of months in this formula might be of some interest. Those knowing that the Mayan calendar had 11 months and that Moon is receding from Earth might rush to check whether a transition from $v/11$ to $v/12$ state has occurred after the Mayan culture ceased to exist: the increase of the orbital radius by about 3 per cent would be required! Returning to a more serious mode, an interesting question is whether light satellites of Earth consisting of dark matter at larger space-time sheets could be present. For instance, in [L4] I have discussed the possibility that the larger space-time sheets of Earth could carry some kind of intelligent life crucial for the bio-control in the Earth's length scale.

The period corresponding to the lowest energy state is from the ratio of the masses of Earth and Sun given by $M_E/M_S = (5.974/1.989) \times 10^{-6}$ given by $T_E = (M_E/M_S) \times T_S = .2595$ s. The corresponding frequency $f_E = 3.8535$ Hz frequency is at the lower end of the theta band in EEG and is by 10 per cent higher than the p-adic frequency $f(251) = 3.5355$ Hz associated with the p-adic prime $p \simeq 2^k$, $k = 251$. The corresponding wavelength is 2.02 times Earth's circumference. Note that the cyclotron frequencies of Nn, Fe, Co, Ni, and Cu are 5.5, 5.0, 5.2, 4.8 Hz in the magnetic field of $.5 \times 10^{-4}$ Tesla, which is the nominal value of the Earth's magnetic field. In [M4] I have proposed that the cyclotron frequencies of Fe and Co could define biological rhythms important for brain functioning. For $v_0/12$ associated with Moon orbit the period would be 7.47 s: I do not know whether this corresponds to some bio-rhythm.

It is better to leave for the reader to decide whether these findings support the idea that the super conducting cold dark matter at the magnetic

flux tubes could perform bio-control and whether the gravitational quantum states and ordinary quantum states associated with the magnetic flux tubes couple to each other and are synchronized.

3.6 p-Adic length scale hypothesis and $v_0 \rightarrow v_0/5$ transition at inner-outer border for planetary system

$v_0 \rightarrow v_0/5$ transition would allow to interpret the orbits of outer planets as $n \geq 1$ orbits. The obvious question is whether inner to outer zone as $v_0 \rightarrow v_0/5$ transition could be interpreted in terms of the p-adic length scale hierarchy [E5, TGDpad].

a) The most important p-adic length scale are given by primary p-adic length scales $L(k) = 2^{(k-151)/2} \times 10$ nm and secondary p-adic length scales $L(2, k) = 2^{k-151} \times 10$ nm, k prime.

b) The p-adic scale $L(2, 139) = 114$ Mkm is slightly above the orbital radius 109.4 Mkm of Venus. The p-adic length scale $L(2, 137) \simeq 28.5$ Mkm is roughly one half of Mercury's orbital radius 57.9 Mkm. Thus strong form of p-adic length scale hypothesis could explain why the transition $v_0 \rightarrow v_0/5$ occurs in the region between Venus and Earth ($n = 5$ orbit for v_0 layer and $n = 1$ orbit for $v_0/5$ layer).

c) Interestingly, the *primary* p-adic length scales $L(137)$ and $L(139)$ correspond to fundamental atomic length scales which suggests that solar system be seen as a fractally scaled up "secondary" version of atomic system.

d) Planetary radii have been fitted also using Titius-Bode law predicting $r(n) = r_0 + r_1 \times 2^n$. Hence one can ask whether planets are in one-one correspondence with primary and secondary p-adic length scales $L(k)$. For the orbital radii 58, 110, 150, 228 Mkm of Mercury, Venus, Earth, and Mars indeed correspond approximately to $k = 276, 278, 279, 281$: note the special position of Earth with respect to its predecessor. For Jupiter, Saturn, Uranus, Neptune, and Pluto the radii are 52, 95, 191, 301, 395 Mkm and would correspond to p-adic length scales $L(280 + 2n)$, $n = 0, \dots, 3$. Obviously the transition $v_0 \rightarrow v_0/5$ could occur in order to make the planet-p-adic length scale one-one correspondence possible.

e) It is interesting to look whether the p-adic length scale hierarchy applies also to the solar structure. In a good approximation solar radius .696 Mkm corresponds to $L(270)$, the lower radius .496 Mkm of the convective zone corresponds to $L(269)$, and the lower radius .174 Mkm of the radiative zone (radius of the solar core) corresponds to $L(266)$. This encourages the hypothesis that solar core has an onion like sub-structure corresponding to various p-adic length scales. In particular, $L(2, 127)$ ($L(127)$) corresponds

to electron) would correspond to 28 Mm. The core is believed to contain a structure with radius of about 10 km: this would correspond to $L(231)$. This picture would suggest universality of star structure in the sense that stars would differ basically by the number of the onion like shells having standard sizes.

Quite generally, in TGD Universe the formation of join along boundaries bonds is the space-time correlate for the formation of bound states. This encourages to think that (Z^0) magnetic flux tubes are involved with the formation of gravitational bound states and that for $v_0 \rightarrow v_0/k$ corresponds either to a splitting of a flux tube resembling a disk with a whole to k pieces, or to the scaling down $B \rightarrow B/k^2$ so that the magnetic energy for the flux tube thickened and stretched by the same factor k^2 would not change.

4 Some applications to condensed matter and biology

Dark matter hierarchy has a wide spectrum of biological applications. Examples are a model for high T_c super-conductivity as a quantum critical phenomenon involving phases with different values of Planck constant [J1, J2, J3], a model for a hierarchy of EEGs based on the model of super-conductivity and on the notion of dark magnetic body [M3, F9, J6], the notion of dark "N-atoms" (N corresponds to number of sheets in multiple covering of CP_2 by M^4 points suggesting how symbolic representations and language like structures emerge already at the level of bio-molecules [F9, L2, J6].

Planck constant can have also values smaller than ordinary Planck constant given in terms of ruler and compass rationals. Hydrinos (hydrogen atoms with fractional principal quantum number) reported by Mills [10] could be understood in this framework [A9]. In this model the states with fractional principal quantum number predicted by q-Laquerre equation [A9] would serve as intermediate states for transitions to dark matter phase. Here only two examples are briefly discussed.

4.1 Exceptional groups and structure of water

By McKay correspondence finite subgroups of $SU(2)$ correspond to subset of ADE groups which has led to a proposal that TGD could be able to mimic corresponding gauge theories using the states of group algebras of finite sub-groups. The Dynkin diagrams of exceptional Lie groups E_6 and E_8

correspond to exceptional subgroups of rotation group in the sense that they cannot be reduced to symmetry transformations of plane. They correspond to the symmetry group $S_4 \times Z_2$ of tetrahedron and $A_5 \times Z_2$ of dodecahedron or its dual polytope icosahedron (A_5 is 60-element subgroup of S_5 consisting of even permutations). Maximal cyclic subgroups are Z_4 and Z_5 and thus their orders correspond to Fermat polygons. Interestingly, $n = 5$ corresponds to minimum value of n making possible topological quantum computation using braids and also to Golden Mean.

There is evidence for an icosahedral clustering in water [7]. Synaptic contacts contain clathrin molecules which are truncated icosahedrons and form lattice structures and are speculated to be involved with quantum computation like activities possibly performed by microtubules. Many viruses have the shape of icosahedron. One can ask whether these structures could be formed around templates formed by dark matter corresponding to 120-fold covering of CP_2 points by M_{\pm}^4 points and having $\hbar(CP_2) = 5\hbar_0$ perhaps corresponding color confined light dark quarks. Of course, a similar covering of M_{\pm}^4 points by CP_2 could be involved.

4.2 Aromatic rings and large \hbar phases

Aromatic rings contain odd number of π delocalized electron pairs with atoms in the same plane. The delocalization of π electrons in the ring is used to explain the stability of these compounds [8]. Benzene is the classical example of this kind of structure. Delocalization and anomalous DNA conductivity [9] suggest interpretation in terms $n_a = 5$ or $n_a = 6$ phase (note that these integers correspond to ruler and compass polygons). DNA conductivity would result from overlap of electrons between rings along DNA strand. Delocalization might give also rise to Cooper pairs [J1].

Aromatic rings consisting of 5 or 6 carbons are very common in biology. DNA basis have been already mentioned. Carbohydrates consist of monosaccharide sugars of which most contain aromatic ring (glucose used as metabolic fuel are exception). Monoamine neurotransmitters are neurotransmitters and neuromodulators that contain one amino group that is connected to an aromatic ring by a two-carbon chain (-CH₂-CH₂-). The neurotransmitters known a monoamines are derived from the four aromatic amino acids phenylalanine, tyrosine, histidine, tryptophan. Also norepinephrine, dopamine, and serotonin involve aromatic rings As a rule psychoactive drugs involve aromatic rings: for instance, LSD contains four rings.

These observations inspire the question whether the compounds containing aromatic rings serve as junctions connecting pre- and postsynaptic

neurons and induce Josephson currents between them. If Josephson radiation codes for the mental images communicated to the magnetic body, the psychoactive character of these compounds could be understood. One can also ask whether these compounds induce quantum criticality making possible generation of large \hbar phases?

4.3 Model for a hierarchy of EEGs

For the model of dark matter hierarchy appearing in the model of living matter one has $n_a = 2^{11k}$, $k = 1, 2, 3, \dots, 7$ for cyclotron time scales below life cycle for a magnetic field $B_d = .2$ Gauss at $k = 4$ level of hierarchy (the field strength is fixed by the model for the effects of ELF em fields on vertebrate brain at harmonics of cyclotron frequencies of biologically important ions [M3]). Note that B_d scales as 2^{-11k} from the requirement that cyclotron energy is constant.

A successful model of EEG emerges explaining its band structure and narrow resonances inside bands. EEG can be interpreted in terms of communications from cell membrane to magnetic body using dark Josephson radiation and the control of genome by magnetic body using dark cyclotron radiation. DNA strands would be organized at magnetic flux sheets like lines of text on a page of book. Super-genome would code coherent gene expression at the level of organs and hyper-genome containing super-genomes of different organisms as text lines would be responsible for coherent gene expression at the level of populations.

The hierarchical structure of magnetic body implies a hierarchy of EEGs and ordinary EEG corresponds to a magnetic body with size of order Earth from Compton length of EEG photons. The large value of \hbar guarantees that dark EEG photons are above thermal threshold and therefore not masked by the thermal noise. Great leaps in evolution would naturally correspond to an emergence of a new level in dark matter hierarchy at the level of individual organism.

The not easily acceptable general prediction is that the field bodies associated with living matter would have sizes up to light life. On the other hand, Libet's findings about strange time delays of consciousness can be understood in terms of magnetic body of size of order Earth.

5 Summary and outlook

The predicted dark matter hierarchy means giving up the reductionistic world view. Fractality and possibility to used simple scaling arguments

makes this vision highly predictive and testable. Of course, a lot remains to be understood. For instance, it is not yet clear whether the two interpretations of the parameter v_0 appearing in the model of planetary orbits are mutually consistent.

The new view has also implications for elementary particle -, nuclear -, and condensed matter physics [F8, F9, J6, J1, J2, J3]. Darkness of valence quarks could allow improved understanding of color confinement. Dark variants of electro-weak gauge bosons and gluons with zoomed up Compton wave length might be directly relevant to the understanding of even ordinary condensed matter [F9]. High T_c super-conductivity represents one particular condensed matter application in which zoomed up electrons play a role [J1].

Perhaps the most fascinating applications of the theory would be to living systems and to quantum model of brain. For instance, I have proposed that charge entanglement over macroscopic distances made possible by dark W bosons might be a fundamental mechanism in quantum control in living matter.

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Appendix: Tables comparing predicted and observed radii of exoplanets

The tables below represent the comparison of predictions of TGD based model for the orbital radii with known radii in the case of exoplanets (the model is discussed in section "Orbital radii of exoplanets). In the tables R denotes the value of minor semiaxis of the planetary orbit using AU as a unit and M the mass of star using solar mass M_S as a unit. n is the value of the principal quantum number and R_1 the radius assuming $X = (r/s)^2 = 1$ and R_2 the value for the best choice of X as ratio of "ruler and compass integers". The data about radii of planets are from tables at <http://exoplanets.org/almanacframe.html> and star masses from the references contained by the tables.

Star Name	R	M	n	R1	R1/R	r	s	R2/R
HD73256	0.037	1.05	1	0.042	1.14	16	15	1.00
HD83443	0.040	0.79	1	0.032	0.79	15	17	1.01
HD46375	0.040	1.00	1	0.040	1.00	1	1	1.00
HD179949	0.040	1.24	1	0.050	1.24	17	15	0.97
HD187123b	0.040	1.06	1	0.042	1.06	1	1	1.06
HD120136	0.050	1.30	1	0.052	1.04	1	1	1.04
HD330075	0.046	0.70	1	0.028	0.61	4	5	0.95
BD-103166	0.050	1.10	1	0.044	0.88	15	16	1
HD209458	0.050	1.05	1	0.042	0.84	16	17	0.95
HD76700	0.050	1.00	1	0.040	0.8	15	17	1.03
HD217014	0.050	1.06	1	0.042	0.85	15	16	0.96
HD9826b	0.059	1.30	1	0.052	0.88	15	16	1.00
HD49674	0.060	1.00	1	0.040	0.67	5	6	0.96
HD68988	0.070	1.20	1	0.048	0.69	5	6	0.99
HD168746	0.065	0.88	1	0.035	0.54	3	4	0.96
HD217107	0.070	0.98	1	0.039	0.56	3	4	1
HD162020	0.074	0.75	1	0.030	0.41	2	3	0.91
HD130322	0.088	0.79	1	0.032	0.36	3	5	1
HD108147	0.102	1.27	1	0.051	0.50	3	4	0.89
HD38529b	0.129	1.39	1	0.056	0.43	2	3	0.97
HD75732b	0.115	0.95	1	0.038	0.33	3	5	0.92
HD195019	0.140	1.02	2	0.163	1.17	16	15	1.02
HD6434	0.150	0.79	2	0.126	0.84	15	16	0.96
HD192263	0.150	0.79	2	0.126	0.84	15	16	0.96
GJ876c	0.130	0.32	3	0.115	0.89	15	16	1.01
HD37124b	0.181	0.91	2	0.146	0.80	15	17	1.03
HD143761	0.220	0.95	2	0.152	0.69	5	6	0.99
HD75732c	0.240	0.95	2	0.152	0.63	4	5	0.99
HD74156b	0.280	1.27	2	0.203	0.73	5	6	1.05
HD168443b	0.295	1.01	2	0.162	0.55	3	4	0.97
GJ876b	0.210	0.32	4	0.205	0.98	1	1	0.98
HD3651	0.284	0.79	3	0.284	1.00	1	1	1
HD121504	0.320	1.18	2	0.189	0.59	3	4	1.05
HD178911	0.326	0.87	3	0.313	0.96	1	1	0.96
HD16141	0.350	1.00	3	0.360	1.03	1	1	1.03
HD114762	0.350	0.82	3	0.295	0.84	15	16	0.96
HD80606	0.469	1.10	3	0.396	0.84	15	16	0.96
HD117176	0.480	1.10	3	0.396	0.83	15	16	0.94
HD216770	0.460	0.90	3	0.324	0.70	5	6	1.01

Star Name	R	M	n	R1	R1/R	r	s	R2/R
HD52265	0.49	1.13	3	0.41	0.83	15	16	0.94
HD73526	0.65	1.02	4	0.65	1	1	1	1.00
HD82943c	0.73	1.05	4	0.67	0.92	16	17	1.04
HD8574	0.77	1.17	4	0.75	0.97	1	1	0.97
HD169830	0.82	1.40	4	0.90	1.09	17	16	0.97
HD9826c	0.83	1.30	4	0.83	1.00	1	1	1.00
HD202206	0.83	1.15	4	0.74	0.89	15	16	1.01
HD89744	0.89	1.40	4	0.9	1.01	1	1	1.01
HD134987	0.81	1.05	4	0.67	0.83	15	16	0.94
HD12661b	0.82	1.07	4	0.68	0.84	15	16	0.95
HD150706	0.82	0.98	5	0.98	1.20	16	15	1.05
HD40979	0.81	1.08	4	0.69	0.85	15	16	0.97
HD92788	0.95	1.06	5	1.06	1.12	16	15	0.98
HD142	0.97	1.10	5	1.1	1.13	16	15	1.00
HD28185	1.03	0.99	5	0.99	0.96	1	1	0.96
HD142415	1.07	1.03	5	1.03	0.96	1	1	0.96
HD108874b	1.06	1.00	5	1.00	0.94	1	1	0.94
HD4203	1.09	1.06	5	1.06	0.97	1	1	0.97
HD177830	1.14	1.17	5	1.17	1.03	1	1	1.03
HD128311b	1.02	0.80	6	1.15	1.13	1	1	1.13
HD27442	1.18	1.20	5	1.20	1.02	1	1	1.02
HD210277	1.12	0.99	5	0.99	0.88	15	16	1.01
HD82943b	1.16	1.05	5	1.05	0.91	15	16	1.03
HD20367	1.25	1.17	5	1.17	0.94	1	1	0.94
HD114783	1.19	0.92	6	1.32	1.11	1	1	1.11
HD137759	1.28	1.05	5	1.05	0.82	15	17	1.05
HD19994	1.42	1.34	5	1.34	0.94	1	1	0.94
HD147513	1.26	1.11	5	1.11	0.88	15	16	1.00
HD222582	1.35	1.00	6	1.44	1.07	1	1	1.07
HD65216	1.31	0.92	6	1.32	1.01	1	1	1.01
HD141937	1.52	1.10	6	1.58	1.04	1	1	1.04
HD41004A	1.31	0.70	7	1.37	1.05	1	1	1.05
HD160691b	1.87	1.08	7	2.12	1.13	16	15	0.99

Star Name	R	M	n	R1	R1/R	r	s	R2/R
HD52265	0.49	1.13	3	0.41	0.83	15	16	0.94
HD73526	0.65	1.02	4	0.65	1	1	1	1.00

HD82943c	0.73	1.05	4	0.67	0.92	16	17	1.04
HD8574	0.77	1.17	4	0.75	0.97	1	1	0.97
HD169830	0.82	1.40	4	0.90	1.09	17	16	0.97
HD9826c	0.83	1.30	4	0.83	1.00	1	1	1.00
HD202206	0.83	1.15	4	0.74	0.89	15	16	1.01
HD89744	0.89	1.40	4	0.9	1.01	1	1	1.01
HD134987	0.81	1.05	4	0.67	0.83	15	16	0.94
HD12661b	0.82	1.07	4	0.68	0.84	15	16	0.95
HD150706	0.82	0.98	5	0.98	1.20	16	15	1.05
HD40979	0.81	1.08	4	0.69	0.85	15	16	0.97
HD92788	0.95	1.06	5	1.06	1.12	16	15	0.98
HD142	0.97	1.10	5	1.1	1.13	16	15	1.00
HD28185	1.03	0.99	5	0.99	0.96	1	1	0.96
HD142415	1.07	1.03	5	1.03	0.96	1	1	0.96
HD108874b	1.06	1.00	5	1.00	0.94	1	1	0.94
HD4203	1.09	1.06	5	1.06	0.97	1	1	0.97
HD177830	1.14	1.17	5	1.17	1.03	1	1	1.03
HD128311b	1.02	0.80	6	1.15	1.13	1	1	1.13
HD27442	1.18	1.20	5	1.20	1.02	1	1	1.02
HD210277	1.12	0.99	5	0.99	0.88	15	16	1.01
HD82943b	1.16	1.05	5	1.05	0.91	15	16	1.03
HD20367	1.25	1.17	5	1.17	0.94	1	1	0.94
HD114783	1.19	0.92	6	1.32	1.11	1	1	1.11
HD137759	1.28	1.05	5	1.05	0.82	15	17	1.05
HD19994	1.42	1.34	5	1.34	0.94	1	1	0.94
HD147513	1.26	1.11	5	1.11	0.88	15	16	1.00
HD222582	1.35	1.00	6	1.44	1.07	1	1	1.07
HD65216	1.31	0.92	6	1.32	1.01	1	1	1.01
HD141937	1.52	1.10	6	1.58	1.04	1	1	1.04
HD41004A	1.31	0.70	7	1.37	1.05	1	1	1.05
HD160691b	1.87	1.08	7	2.12	1.13	16	15	0.99

Star Name	R	M	n	R1	R1/R	r	s	R2/R
HD23079	1.65	1.10	6	1.58	0.96	1	1	0.96
HD186427	1.67	1.01	6	1.45	0.87	15	16	0.99
HD4208	1.67	0.93	7	1.82	1.09	16	15	0.96
HD114386	1.62	0.68	8	1.74	1.07	17	16	0.95
HD213240	2.03	1.22	6	1.76	0.87	15	16	0.98
HD10647	2.10	1.07	7	2.10	1.00	1	1	1
HD10697	2.13	1.10	7	2.16	1.01	1	1	1.01
HD95128b	2.09	1.03	7	2.02	0.97	1	1	0.97
HD190228	2.00	0.83	8	2.12	1.06	1	1	1.06
HD114729	2.08	0.93	7	1.82	0.88	15	16	1
HD111232	1.97	0.78	8	2.00	1.01	1	1	1.01
HD2039	2.19	0.98	7	1.92	0.88	15	16	1
HD136118	2.40	1.24	7	2.43	1.01	1	1	1.01
HD50554	2.32	1.07	7	2.09	0.9	15	16	1.02
HD9826d	2.53	1.30	7	2.55	1.01	1	1	1.01
HD196050	2.43	1.10	7	2.16	0.89	15	16	1.01
HD216437	2.43	1.07	8	2.74	1.13	17	15	0.88
HD216435	2.70	1.25	7	2.45	0.91	1	1	0.91
HD169830c	2.75	1.40	7	2.74	1	1	1	1
HD106252	2.54	0.96	8	2.46	0.97	1	1	0.97
HD12661c	2.60	1.07	8	2.74	1.05	1	1	1.05
HD23596	2.86	1.30	7	2.55	0.89	15	16	1.01
HD168443c	2.87	1.01	8	2.59	0.9	15	16	1.03
HD145675	2.85	1.00	8	2.56	0.9	15	16	1.02
HD11964b	3.10	1.10	8	2.82	0.91	16	17	1.03
HD39091	3.29	1.10	9	3.56	1.08	17	16	0.96
HD38529c	3.71	1.39	8	3.56	0.96	1	1	0.96
HD70642	3.30	1.00	9	3.24	0.98	1	1	0.98
HD33636	3.56	0.99	9	3.21	0.9	15	16	1.03
HD95128c	3.73	1.03	10	4.12	1.1	16	15	0.97
HD190360	3.65	0.96	10	3.84	1.05	1	1	1.05
HD74156c	3.82	1.27	9	4.11	1.08	1	1	1.08
HD22049	3.54	0.80	11	3.87	1.09	16	15	0.96
HD30177	3.86	0.95	10	3.80	0.98	1	1	0.98
HD89307	4.15	0.95	10	3.80	0.92	1	1	0.92
HD72659	4.50	0.95	11	4.60	1.02	1	1	1.02
HD75732d	5.90	0.95	13	6.42	1.09	16	15	0.96